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MODERN CONCEPTS OF CARDIOVASCULAR DISEASE

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Heart Activation in Cardiac Arrest

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Open-chest heart massage and defibrillation have been the standard practice for years in cases of cardiac arrest. In 1951, at the School of Medicine of Johns Hopkins University, a study of the possibility of arresting ventricular fibrillation without resorting to thoracotomy was begun. In 1956, Zoll et al.[1,2] (of Beth Israel Hospital and Harvard Medical School, Boston) reported that they had successfully defibrillated human hearts in ventricular fibrillation by an electric countershock sent transversely through the chest.

In March 1957, the Hopkins Closed-Chest A.C. Defibrillator[3] was applied for the first time to a patient suffering from Stokes-Adams syndrome. This defibrillator sends through the chest a 60-c.p.s. A.C. current of 5 amperes for one-quarter of a second at a potential of 440 volts. One electrode is placed on the suprasternal notch, and the other is applied 2 or 3 cm. below the left nipple. From 1.5 to 2 amperes of the defibrillating current flows longitudinally through the heart and depolarizes the myocardium.

The apparatus is shown in figure 1; it is now in use in a number of hospitals in the eastern part of the United States. The equipment is mounted on a movable cart 16 inches deep,

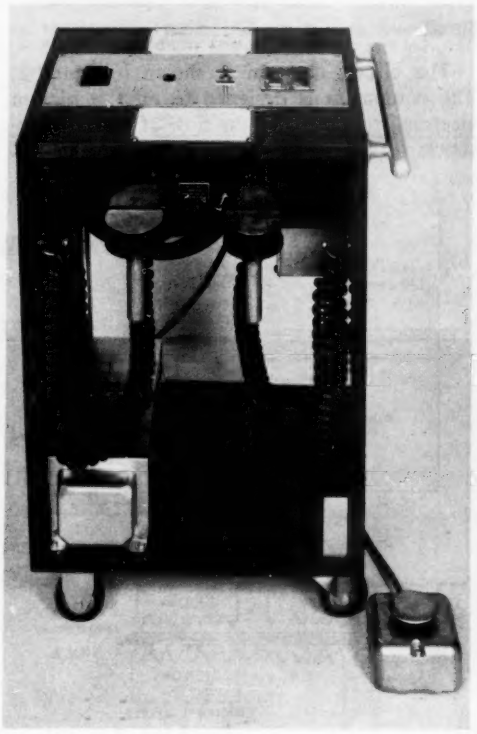

Figure 1. *Hopkins Closed-Chest Defibrillator. (By courtesy of Charles H. Weber, Photographer, Illustration Division, Johns Hopkins University.)*

22 inches wide, and 30 inches high; the power supply is 110 volts, 60 c.p.s., A.C. This

voltage is increased to 220 and 440 volts by a low-impedance transformer mounted on the lower shelf of the cart. Visible on the top shelf are a main circuit-breaker switch, a pilot light to indicate that the power is on, and a selector switch which may be set for adults and children (440 volts for adults and 220 for small children). In addition, on the top is a clock-type timer set to deliver a one-quarter-second countershock. The circular electrodes, of copper, are 58 square cm. in area and are mounted on plastic handles, held in clips on the front. The foot switch, shown on the floor, is conveniently placed for the surgeon, so that when he is ready to apply the countershock, he steps on the switch, sending the current through the patient's chest for one-quarter of a second. The switches and contactors are enclosed in an explosion-proof case.

Circuit

The circuit diagram is shown in figure 2. The equipment is designed to offer minimum electrical resistance to the flow of the countershock. The 3 K.V.A. transformer for increasing the voltage from 110 to 440 volts is of low impedance, and its primary and secondary windings are separated by insulation. The clock-operated timer is an industrial type and requires no warm-up time. To eliminate the possibility of an electrical contactor relay chattering and thereby opening and closing the circuit during the one-quarter-second countershock, it is of the double-pole type; both poles are connected in parallel. The contacts are of tungsten. The copper electrodes are cemented to plastic discs, one-quarter of an inch thick, fastened to concentric plastic handles, one inch in diameter. These are grasped by the surgeon and facilitate his applying them, with a pressure of some 8 or 10 pounds, to a patient's chest, as shown in figure 3. The handles are equipped with guards to prevent the hands of the surgeon from touching the patient. The foot switch is a standard rugged commercial item.

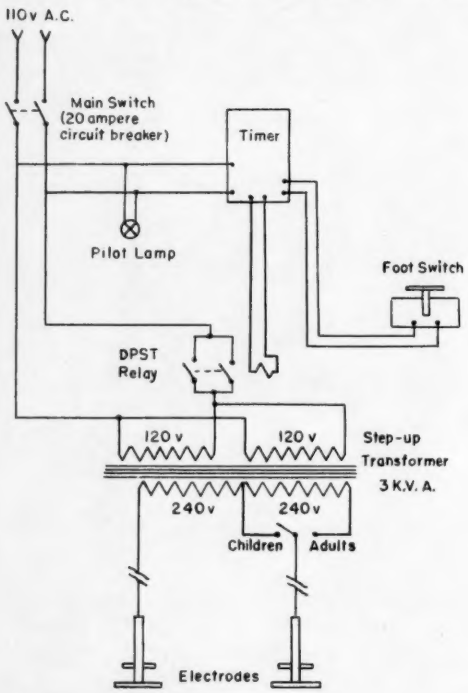

Figure 2. *Circuit diagram of the closed-chest defibrillator.*

It should be noted that the surgeon or operator of the Hopkins Defibrillator has complete control of the electrodes and of the application of the countershock. This eliminates the possibility of someone receiving an electric shock through a misunderstanding of signals. This has happened when another individual controlled the actuating footswitch or button.

At the Johns Hopkins Hospital, this type of defibrillator has been employed more than 100 times to defibrillate human hearts. It has eliminated the need for thoracotomy. If, on some occasions, a second shock is necessary, this should be applied immediately after the initial shock. It has been used in one instance

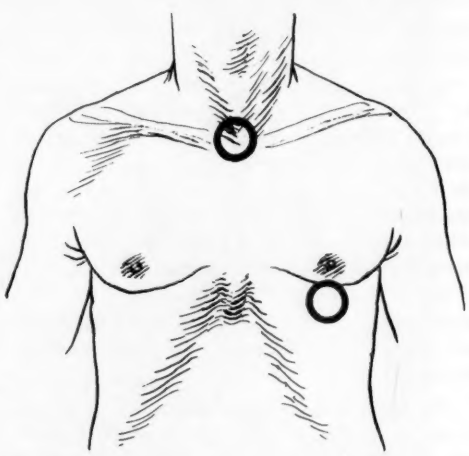

Figure 3. *Electrodes on chest.*

to defibrillate the heart of a 23-year-old woman whose chest had been opened for cardiac massage. In this case, the rib spreaders were removed, allowing the ribs to spring back. The countershock from the closed-chest defibrillator applied on the outside of the chest arrested the fibrillation.

Although the closed-chest A.C. defibrillator has proven to be effective and reliable in arresting ventricular fibrillation, its countershock must be sent through the victim's chest within less than three minutes after the onset of fibrillation; otherwise, the heart will be too anoxic to resume pressure-producing contractions spontaneously and the central nervous system may be injured. This time limitation severely restricts the use of a closed-chest defibrillator to locations adjacent to the patient suffering the emergency. The problem has been: How can this time limitation be overcome? Specifically, how can blood be circulated without opening the chest and massaging the heart directly?

CLOSED-CHEST CARDIAC MASSAGE

A search of the literature furnished a number of attempts to accomplish this. None of the methods described were very promising, with the exception of one by Boehm,[4] who in 1878 squeezed the chest of the cat between his two hands and produced circulation. He was successful in restoring the heartbeat of one-half of his animals. In 1947, Gurvich and Yuniev[5] reported that they had been able to maintain the tone of the fibrillating dog's heart by pressing on the chest for periods of seven to eight minutes, and that upon defibrillation the heart would spontaneously resume autogenous beats. They gave no details, and correspondence with them failed to elicit any information as to their techniques.

Using the dog as the experimental animal,[6] it was found possible, by applying rhythmic pressure on the sternum, to provide sufficient circulation to maintain the tone of the fibrillating heart and to keep the brain alive for half an hour. Upon the application of a defibrillating shock, the dog's heart resumed spontaneous effective contractions and the animal survived.

With the dog in a supine position, the best results were obtained when firm rhythmic pressures, at the rate of 100 to 120 per minute, were applied vertically downward by the heel of the hand at the lower third of the sternum. Systolic pressures of 60 to 100 mm. Hg result, and the flow in the carotid artery ranges from 40 to 60 per cent of normal.

Application to Man

When in man the circulation ceases because the heart is in cardiac arrest and the breathing stops, oxygenated blood is no longer supplied to the tissues. Two things are necessary: (1) the ventilation of the lungs, and (2) the pumping of oxygenated blood to the body. The lungs may be supplied with oxygen by mouth-to-mouth insufflation, or by intubation or mask and the use of oxygen or air. Closed-chest cardiac massage will circulate the oxygenated blood and maintain the patient alive.

The patient in cardiac arrest should be placed in a supine position, preferably on a firm support such as the floor, a table, or a bed board (fig. 4). Provide a patent airway by inserting a tube or extending the neck and pulling the jaw up, as in mouth-to-mouth insufflation. Kneel beside the patient and place your hands on the center of his chest. To find the exact spot: locate the xiphoid and place the heel of the lower hand, with the other hand on top of it, on the sternum just above the xiphoid. Now press vertically downward, using the weight of your body, to push the sternum in for a distance of an inch to one-and-one-half inches. This action compresses the heart between the sternum and the vertebral column and forces the blood out of the heart and into the lungs and the systemic circulation. Now release the pressure, lifting your hands slightly. This allows the patient's chest to expand fully and the right and left ventricles to refill. Repeat the cycle about 60 to 80 times per minute.

If you are the only person present, rapidly ventilate the patient's lungs by giving the patient three or four deep breaths, mouth-to-mouth. Then start massage and, after about a minute or a minute and a half, stop the massage and fill his lungs again with fresh air. If there is someone else present, have him ventilate the lungs simultaneously. There is no need to synchronize the two lifesaving procedures.

CLINICAL APPLICATIONS

The transfer of closed-chest cardiac massage to man has been made with unusual facility due to the more favorable thoracic anat-

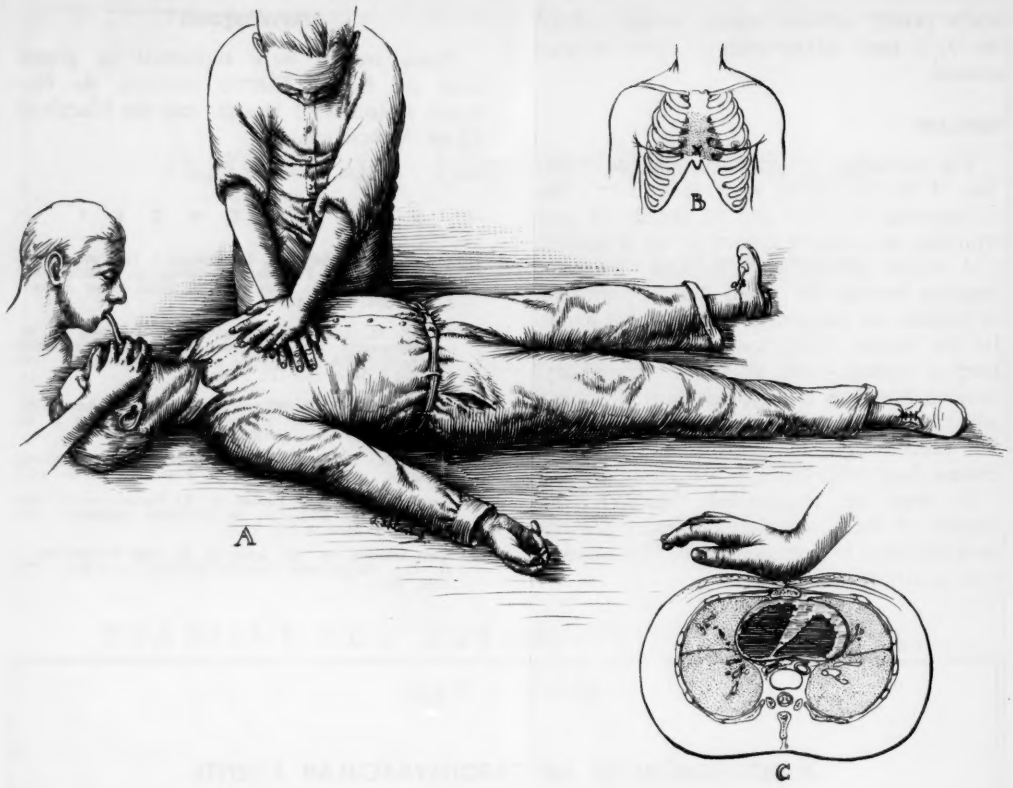

Figure 4. *Simultaneous application of closed-chest massage and artificial respiration.*

omy. The human mediastinum is fixed. The heart, particularly in the case of standstill or ventricular fibrillation, dilates and almost entirely fills the space between the sternum and thoracic spine; the liver, below the diaphragm, escapes compression during this maneuver. The chest of the unconscious adult is remarkably flexible. Applying rhythmic, intermittent, strong vertical pressure centrally on the lower third of the sternum has resulted in maintenance of sufficient circulation to keep the brain alive in a human being whose heart remained in asystole for two hours before it resumed forcible contraction. Not only has it been possible to re-establish automatic cardiac activity from asystole, but also to provide adequate circulation in the presence of ventricular fibrillation until external defibrillation could be accomplished.

Resuscitation from cardiac arrest has been attempted in 84 cases at the Johns Hopkins Hospital, as set forth in table 1. A total of 68 patients have suffered 84 arrests. Of these, 59, or 70 per cent, were resuscitated to their prearrest central nervous system status.

Ventricular fibrillation was present in 15 of these patients. All were defibrillated, although 4 repeatedly reverted to ventricular fibrillation. Of the 15, 7 were returned to their pre-

TABLE 1

RESUSCITATIONS FROM CARDIAC ARRESTS

	Number of patients	Number of attempted resuscitations	Resuscitation CNS OK	Per cent resuscitated
Operating and recovery rooms	18	21	21	100
Myocardial infarction	11	12	4	33
Cardiac	16	20	14	70
Miscellaneous	23	31	20	64
Totals	68	84	59	70

arrest central nervous system status, and of the 7, 5 died subsequently of their primary disease.

SUMMARY

The technique for accomplishing defibrillation of the fibrillating ventricle in man without opening the chest and the details for constructing an effective apparatus are described.

A simple and effective method of cardiac massage through the closed chest is presented. It requires no gadgets, but merely two hands. By this means, circulation can be provided to keep a human being alive and supply oxygenated blood to the hypoxic heart in standstill while therapy is administered, or provide the needed time to summon and supply a closed-chest defibrillator.

It must be emphasized, however, that neither of these techniques relieves the disease that may have caused the cardiac arrhythmia or arrest.

Acknowledgment

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